THE SIGNIFICANCE OF WEATHER MODIFICATION TO A FORESTER

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Paper presented at SAF - Sept. 14-17, 1953 - Meeting
held at Colorado Springs, Colorado

4249

9/10/53

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In the progress of science over the last 100 years, one generalization might be made. We have made most progress in our knowledge of the land, less in our knowledge of the sea and least of all, of the atmosphere around and/ above us. In the last fifty years we have ushered in what some call the air age. By plane, we think nothing of travelling from coast to coast across the continent of North America and there are many here who have been half way around the world and back or even around the globe. Sixty miles is now only a hop horizontally but sixty miles vertically? - that is a different matter. Sixty miles above the earth's surface or even six miles above, we enter a strange and mostly unexplored environment. Our use of the air as a medium of travel and the possibility of jet travel in the stratosphere have urgently focused attention of scientists on the many unknowns in this environment at increasing distances out and to the great supposed void beyond the earth's gravity we usually call "space." New knowledge is developing rapidly and many of us will see it reflected, not just in the "space man" comics but in our children's school books in a few years.

But why should a forester be concerned about the atmosphere, especially the upper atmosphere? There are some very practical reasons. Some of them are going to be very ably presented by Mr. J. S. Barrows in his paper describing the participation of our Fire Research group in a pioneering project with the Munitalp Research Foundation and the Weather Bureau that will give us a new understanding of the evolution and behavior of fire-setting lightning storms. Many of you here will recall that the need for such knowledge was appreciated by foresters 30 years ago. A good many administrative studies were carried

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out in an effort to track lightning storms and to define areas in which they concentrated. Such studies were worth while, and we learned a great deal from them. But there were too many gaps in basic knowledge of the physical relationships for either the physicist or the meteorologist to help us much in interpreting what we observed. Now some of these gaps are closing in and we at last have a chance to remove the mystery and to deal more effectively with the phenomena we know as dry lightning storms and lightning fires.

But the importance of lightning storms in the West is only one aspect of the pattern of climate and weather with which we are all concerned. Practicing foresters are as dependent on climate and weather for success in growing trees and forage as the farmer. In fact, they are somehwat more at the mercy of the weather than the agriculturist, since the latter has more opportunity to make artificial modifications of the micro-climate particularly in terms of the moisture supply. There is little need to remind you that local and general weather conditions determine the success or failure of both natural and artificial seeding of trees and forage plants and the success of our planting efforts. It determines rates of growth and species adaptation. It determines liabilities from floods, blow down, ice breakage, frost and drought. It sets time limits and schedules to all kinds of forest operations and uses.

In research nearly all our field experiments must take account of variations in the weather as one of the controlling variables.

In our forest fire research we are particularly conscious of weather factors because both the liability to fires starting and the behavior and spread of fires are directly controlled by weather elements. Much of our progress in forest fire control can be credited to the studies of weather-fire relationships as exemplified by the contributions of our late pioneer and explorer in the

fire-weather field, Harry T. Gisborne. The fire danger rating systems and the development and use of fire-weather forecasts were natural products of such work. Both are still imperfect, but the daily dependence placed on them by fire agencies is convincing evidence of the importance of such knowledge to fire control.

But Harry Gisborne felt, as I do now, that we were just on the verge of new discoveries and developments in weather science of importance to fire control that would dwarf everything that had gone before. He had two reasons. One was the realization that one very important weather factor had been left out in the measurement and prediction of fire behavior. That factor was the degree of local atmospheric stability in the vicinity of a going fire. The second reason was the new knowledge on cloud formation and dissipation that offered a vista of things to come where we might prevent lightning fires and perhaps exercise to some degree other desired forms of local weather modification. It is still too early to predict how important new knowledge in these directions will prove to the forester, but the prospects are promising. Already we have made progress in relating instability of the air to fire bheavior. The paper presented earlier in this meeting by R. Keith Arnold and C. C. Buck, entitled "Blow-up Fires - Silviculture or Weather Problems?" gives you some of the things we have learned from recent research. Mr. George Byram of the Southeastern Station is making an intensive study of the kinds of local air turbulence that cause dangerous fire behavior and the Weather Bureau is cooperating closely in an effort to identify criteria that can be used to forecast such situations.

Progress in weather modification through cloud seeding is already a long and involved story even though its history goes back only to 1946. You have all heard a great deal about it, and both popular and technical literature is available from several sources.

It is my purpose here to confine the remainder of my comments to a non-technical summary of some of the many factors that will continue to make developments in this field of much interest and much potential importance to the forester as well as to the farmer.

A central fact to the layman is that 0° Centigrade or 32° Farenheit are the melting point of ice, but not necessarily the freezing point of water or water vapor. As a consequence, water vapor in the air may, and often does, remain in liquid form in a supercooled state. This has importance because precipitation in our middle latitude is assumed to start with the formation and growth of ice crystals to the point where they yield to gravity and fall out of the cloud to come down as rain or snow. Dr. Vincent Schaefer of the General Electric discovered that this does not occur automatically until a critical temperature of - 39C is reached. Between this point and 0° C ice crystal formation depends on the presence of suitable nucleii on which such ice crystals can grow. The number of such nucleii varies enormously in nature. In studies he conducted there were less than 100 per cu. meter of air 50% of the time. But maximums of as high as ten million per cubic meter were recorded. So the variations were found to be in the order of a million.

The best of natural nucleii are derived from clay, loess, volcanic ash and salt particles. They become effective at temperatures of -12 to -15C. Other common ones become effective at -20 to -30°.

In a supercooled cloud of water vapor, dry ice pellets immediately produce a myriad of ice crystals because its temperature of -78°C cools the water droplets quickly below their critical temperature of -39°. This produces an abundance of natural ice nucleii even though the exposure is only for a fraction of a second.

One of Schaefer's associates in a search for nucleii that would be more effective than the common nucleii that occur, hit on silver iodide as a nucleating agent because its crystal formation was nearly identical to that of the ice crystal. It proved to be effective at -4°C as compared to the -12° to -30°C temperatures required for most natural nucleii.

These are the discoveries on which cloud seeding experiments were based. As you know, they have led to extensive commercialized cloud seeding and to a great deal of controversy as to their net value in increasing precipitation.

Experimentally, some striking results from seeding have been produced by both methods when deep cumulus clouds were seeded under the right combination of favorable conditions. The effects produced are then in the nature of a chain reaction or trigger action, like starting a fire from a single spark. But so far neither complete measurement of existing factors nor control of results can be assured in the fire atmosphere, so many unknowns enter in.

It is possible to overseed by providing so many nucleii that ice crystals cannot grow large enough to precipitate out. This relationship too has been applied by commercial cloud seeders in efforts to prevent rain.

Under drought conditions when there is a scarcity of moisture aloft, there is no possibility of correcting the situation by seeding. There must be a supply of moist air and cloud-forming processes must be operating to replenish it. When there are abundant natural nucleii present, artificial seeding might conceivably reduce the chances of precipitation rather than to increase them. Under some conditions, silver iodide may oxidize in the air and lose its effectiveness. So it goes.

The numerous evaluations of commercial cloud seeding that have been undertaken by the Weather Bureau and others throw doubt on the economic returns to the rancher and farmer of the methods now employed. But evaluations are

difficult, because conditions under which seeding of clouds has the best chance of increasing precipitation, are also the conditions under which natural precipitation is likely to occur. We have conducted an analysis of cloud seeding results over the Tillamook burn in Oregon which is the only contract we know of that has been undertaken for the sole purpose of reducing fire danger. We found that kind of situation.

Because of the popularity of this subject, the extensive scale on which commercial cloud seeding is being practiced, and the complete absence of any legislation or regulations dealing with clouds or with the moisture aloft, there have been many lively legal debates on the subject. Wyoming, Colorado, Oregon, Utah and New Mexico have passed state laws on the subject and other states are considering similar laws. In Congress eight bills providing for regulation or experimentation were introduced last year, but none were passed. In the 83rd Congress a compromise bill S-285, now known as Public Law #256, was finally passed and has been signed by the President. It provides for setting up a nine-man advisory committee to be composed of the Secretary or his designee of Defense, Agriculture, Commerce, Interior, Health,Education and Welfare, and the Director of the National Science Foundation and five members from private life to be appointed by the President. It is the duty of this committee to make a complete study and evaluation of public and private experiments in weather control for the purpose of determining the extent to which the U.S. should experiment with, engage in, or regulate activities designed to control weather conditions. The Committee is to submit a final report and recommendations not later than June 30, 1956. Thirty days thereafter it will cease to exist.

The best that can be said of conclusions on effects of cloud seeding to date is pretty well summed up by the May 1953 statement prepared by the

American Meteorological Society.

I quote this statement:

"The Council of the American Meteorological Society has continued to keep in close touch with the development of knowledge in the field of weather modification and control. Although the scientific background is still far from complete, the Council, as a public service, submits the following statements as a summary of present knowledge of weather modification and control. They amplify and extend the similar statements issued by the Council on August 15, 1951.

"1. The seeding of a supercooled cloud with dry ice will usually convert at least a portion of the cloud to ice crystals. Under appropriate conditions such seeding will release variable amounts of precipitation from fairly deep and active cumulus clouds. Small, inactive cumulus clouds are usually dissipated when they are seeded with dry ice. Holes or valleys may be produced in supercooled layer clouds or supercooled fogs by seeding them with dry ice.

"2. The injection of small water drops or salt particles into the bases of deep, warm (non-supercooled) cumulus clouds will usually release variable amounts of rain if the vertical velocities in the clouds are substantial. Small, inactive, warm cumulus clouds may often be partially or completely dissipated by seeding them from above with certain materials; such dissipation may or may not be accompanied by rain of extremely light intensity.

"3. In some cases warm fog and warm stratus may be dissipated in restricted regions by certain seeding agents other than dry ice or silver iodide.

"4. It is known that silver iodide crystals will convert supercooled clouds to ice crystals at temperatures below about $-5^{\circ}C$. It is therefore reasonable to expect that precipitation might be released from supercooled clouds by silver iodide seeding. Experimental evidence of positive results from silver iodide seeding is not yet as convincing as the results of dry ice seedings. Among the possible reasons for poorer results with silver iodide are the lower temperature required, the effect of sunlight on the silver iodide and some uncertainty as to the infection of the proper region of the cloud.

"5. Cloud seeding acts only to trigger the release of precipitation from existing clouds. The release of substantial amounts of precipitation by either natural or artificial means requires the pre-existence of an extensive moisture supply in the form of moist air currents and of active cloud-forming processes. For this reason the meteorological conditions most favorable for the artificial release of precipitation are very much the same as those which usually lead to the natural release of precipitation. This makes the evaluation of the effects of seeding difficult and often inconclusive.

"6. Statistical analyses, by independent agencies, have failed to show that the monthly or seasonal precipitation over a selected target area has been significantly increased by ground-based silver iodide seeding. Although these studies do not preclude the possibility that the precipitation can be increased they suggest that any increase has been relatively small.

"7. Present knowledge of atmospheric processes offers no basis for the belief that the weather or climate of a large portion of the nation can be modified by cloud seeding. The results of experiments which have been conducted to explore such large-scale effects are considered to be inconclusive. Not all of the results are explainable in the light of present knowledge and further experimentation is desirable."

Such a statement must be most discouraging to the enthusiast who believes that we now have at hand the means of changing our climate to order, and it is disappointing too to the rancher and farmer who hope to eliminate drought by such means.

As you are no doubt aware, the major factors that affect our climate such as the sun's radiation, the relation between ocean and land temperatures and the great cyclonic air movements that emanate from the Bering Sea near the North Pole are forces that are still beyond control of man by any foreseeable method. . .

Nevertheless, new scientific progress has been made in understanding the process of cloud formation and dissipation and the physical processes by which precipitation occurs. Only the practical uses to which such information can be put for human benefits are in doubt. They will emerge in due time if continued active experimentation can continue.

Out of such information it is reasonable to expect that continuing records and observations will enable us to define just when and where cloud seeding can produce a desirable local effect. Such effects might take the form of dissipation of certain types of local thunderstorms before they have built up

a dangerous lightning potential, increasing the snow pack during the winter season on critical watersheds and on winter sports areas, perhaps on occasions, help on a going fire at critical times through inducing local showers or by creating suddenly increased humidities and lower temperatures for a time, and in some areas, a net local increase in rainfall to the benefit of forest cover and water yield.

Such possibilities of value to the forest land manager seem more promising at this stage than the purposes for which much money has already been invested in commercial cloud seeding throughout our Western country. The mysteries of air movement and storm development are not yet completely understood. Progress in solving them is a challenging thing to which our own research men should contribute and from which the practicing forester is bound to benefit.